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ORIGINAL RESEARCH

TESTING INFRASPINATUS AND DELTOID MUSCLES WITH NEW TECHNIQUE TO DECREASE DELTOID ACTIVITY DURING TESTING USING EMG ANALYSIS

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ABSTRACT

Background: Muscle strength testing of an injured infraspinatus muscle (IM) is confounded by actions of synergistic muscles such as the posterior deltoid (PD).

Hypothesis/Purpose: The purpose of this study was to describe a condition for testing of the IM that results in less EMG activity of the PD musculature. The researchers hypothesized that greater inhibition of the PD could be achieved through active adduction (AA), creating reciprocal inhibition of the PD.

Study Design: Prospective cohort descriptive study

Methods: Thirty-four (19 females and 15 males) right-handed subjects between the ages of 22- 31 (mean 24.2 years +/- 6.2) with no previous history of shoulder surgery or pathology participated. Surface electrodes were placed over the muscle bellies of the IM and PD of the right shoulder along with a ground electrode over the C7 spinous process. EMG activity was recorded during resisted external rotation in four different testing conditions (seated active and passive adduction, and side-lying active and passive adduction). The order of test positions was randomly assigned, and each subject completed all four positions with appropriate rest. During AA conditions, subjects were asked to adduct the humerus against a sphygmomanometer (using 80% maximum force output) while maximal effort external rotation was manually resisted.

Results: PD activity was significantly less during AA than with no AA ($p < 0.05$) in both test positions. No significant difference occurred between IM EMG activity in the various test conditions.

Conclusion: The results of this study suggest that clinicians can reduce activity of the PD without reducing activity of the IM by using AA of the humerus before applying manual resistance to test the IM during manual muscle testing.

Levels of Evidence: 1b.

Key Words: Electromyography, infraspinatus, infraspinatus test, posterior deltoid, manual muscle testing

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INTRODUCTION

Shoulder rotator cuff injuries are commonly evaluated by medical and rehabilitation professionals. A high predominance of rotator cuff injuries has caused an increased awareness among healthcare practitioners regarding evaluation, rehabilitation, and prevention of further injury to the muscle group.[1] The infraspinatus muscle (IM) has been suggested to be the primary rotator cuff muscle that moves the glenohumoral joint (GH) through external rotation while the shoulder is abducted at 0°.[2] The infraspinatus manual muscle test is a reproducible test in intra-rater and inter-rater reliability studies.[3] The most common muscle injured in the cuff is the IM, with some authors reporting an incidence of 22%-40% of rotator cuff injuries involving the IM, found through MRI and surgery.[4,5]

A practitioner needs to be able to accurately assess the strength of the IM to determine deficits of the muscle being tested and would prefer to utilize the muscle being tested without a contribution of other synergistic muscles. The most commonly described manual muscle test (MMT) position for the IM involves the patient in a side-lying position with the humerus fully adducted, in neutral rotation, and the elbow maintained in 90° of flexion while resistance is applied to the distal arm toward internal rotation.[6-8] Some authors suggest this same test can be performed whether in a seated or standing position.[9,10] During the seated and side-lying testing 0° abducted positions, the posterior deltoid (PD) is activated along with the infraspinatus, which can increase the resisted external rotation torque and thereby change the reported resisted strength of the infraspinatus muscle.[10-12] The position of prone horizontal abduction with the shoulder fully externally rotated and prone external rotation with shoulder at 90° abduction and elbow at 90° of flexion have also been suggested for strengthening of the infraspinatus but are more often used to try to isolate the infraspinatus during rehabilitation programs.[10,13-16] External rotation resisted positions while the shoulder is in adduction and at 90° of elevation, used for testing and treatment of the infraspinatus, lack the ability to reduce or minimize the EMG activity of the deltoid musculature (one of the muscles known to contribute to external rotation torque).[11] Reese, in her muscle testing text, suggests a 90° abducted position with the elbow flexed to 90° to test the external rotators of the glenohumeral joint.[17] This testing position also activates the other external rotators of the shoulder and is not intended to specifically target the IM.[17]

Porter[16] states that when the agonist muscle contracts maximally, the antagonist muscle relaxes maximally, in a process called reciprocal inhibition. This process occurs when motor neurons of the agonist muscle receive excitatory impulses from the afferent nerves and motor neurons that supply the motor antagonist muscles are inhibited by afferent impulses.[15] Thus, contraction of the agonist muscle has been said to elicit relaxation or inhibit the antagonist.[15,18] The deltoid musculature (as a group) is primarily an abductor of the shoulder, and certain portions of this muscle (the PD) can assist in rotation and stabilization of the glenohumeral joint.[8] The use of an isometric contraction into adduction (the use of reciprocal inhibition) may allow a decrease in electrical activity of the deltoid muscle while allowing continued functional activity of the IM.

The purpose of this study was to describe a condition for testing of the IM that results in less EMG activity of the PD musculature. The authors propose that reciprocal inhibition through the use of a significant adduction force at the shoulder while performing external rotation in the seated and side-lying positions with shoulder at 0° and elbow at 90°, will allow the IM to continue to function while decreasing the EMG activity of the synergistic PD muscle.

METHODS

Subjects

Thirty-four subjects between 22-31 years-of-age (mean 24.2 +/- 6.2; 19 females and 15 males) were included. All subjects had normal shoulder function in the dominant shoulder. Normal shoulder function was defined as asymptomatic with regard to pain and functional limitation within the past year. Exclusion criteria included: any past shoulder surgery, prior history of shoulder injections for shoulder pain, and any injury requiring medication or rehabilitation of the shoulder in the year prior to the study. The study was approved by the Institutional Review Board at the University of Central Arkansas.

Instrumentation

Surface EMG data were collected using a Biopac MP36 connected to a PC and was analyzed using Biopac BSL 4.0 software (BioPac Systems, Inc. Goleta, CA). The EMG unit consists of a 24-bit A/D board with differential amplifier characteristics of CMRR > 90dB and an input impedance of 2MΩ. The sampling frequency was set at 1,000 Hz. Data were band-pass filtered (30-500Hz) to decrease movement artifact and extraneous noise and then enveloped with Root Mean Square (RMS) processing using a 50ms window. Self-adhering Biopac EL503 Ag/AgCl electrodes were used for both recording and reference electrodes. A blood pressure cuff and aneroid sphygmomanometer was used to provide feedback in order to determine maximum adduction force and also maintain a consistent level of force during testing.

Procedures:

All volunteers were required to review and give an informed consent prior to participation. The dominant arm of each of the participants was tested and was defined as the extremity used to eat and write. All the subjects were right-hand dominant. The electrode sites were cleaned with alcohol and two electrodes were placed over the posterior deltoid musculature at the lateral border of the spine of the scapula and obliquely angled toward the upper extremity parallel to the fibers. In addition, two electrodes were placed over the infraspinatus musculature muscle belly 4cm below the spine of the scapula over the infrascapular fossa. The electrodes were placed 70 mm apart within the confines of the muscle as described by Criswell[19] and a reference electrode was placed over the C7 spinous process. This array has been used by various authors who have studied surface EMG of the infraspinatus.[20,21] The same tester performed all of the resisted testing on all subjects. Data was collected during 1) sitting, and 2) side-lying test positions. For both positions, a rolled blood pressure cuff was placed between the trunk and medial epicondyle just proximal to the medial epicondyle of the dominant humerus and against the ribcage to determine adductor force of the upper arm during external rotation of glenohumeral joint (GHJ). The cuff was inflated to 20 mmHg and subjects were asked to adduct forcefully to find subject's maximal adduction force output (MFO). Once the MFO was recorded in mmHg, 80% of the individual's MFO was calculated. Active adduction was defined as 80% or higher of each individual's MFO. Passive adduction was defined as 60% or less of each individual's MFO. The subjects were randomly assigned by position and active or passive adduction using research randomizer software (Randomizer.org, Urbaniak and Plous, 2013). Both sitting tests and both side-lying tests were performed in conjunction with each other to reduce the movement of the patient and the strain on the EMG electrodes. The four testing conditions are as follows:

Test A (seated active adduction): The subject was placed in a seated position on a chair with the dominant shoulder adducted to 0° and elbow flexed at 90°. Stabilization was achieved as shown in Figure 1. The subject was then asked to actively adduct the arm against the inflated cuff to attain 80% of individual's MFO. Resistance was then manually applied to failure while maintaining 80% of MFO. One consistent person monitored the amount of MFO along with the subject and feedback was given continuously to maintain consistent pressure on the gauge. (Figure 2)

Figure 1. *Stabilization of the Shoulder in Sitting Testing Position. This is the traditional seated Infraspinatus Test position. The stabilization is performed through the upper scapula by a corollary researcher.*

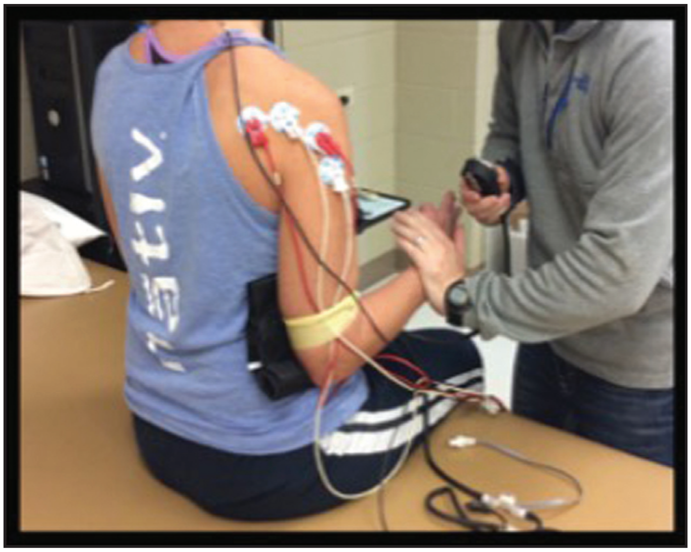

Figure 2. *Test Positions A and B: Seated Active or Passive Abduction. The researcher is applying resistance to external rotation for either condition. In test position A the subject would be actively adducting into the blood pressure cuff at 80% of maximal effort and in test position B the subject would be asked to not adduct into the blood pressure cuff. The stabilization of the scapula would be performed by a second researcher not shown in this picture.*

Test B (seated passive adduction): The subject was positioned the same as in Test A. The subject was then asked to not apply pressure to the cuff (operationally defined as to not exceed 60% of the individual's MFO). Resistance was then manually applied to failure while maintaining less than 60% MFO. Again, one consistent person monitored the amount of MFO along with the subject and feedback was given continuously to not increase the pressure on the gauge. (Figure 2)

Test C (side-lying active adduction): The subject lay on their side on their non-dominant arm on a plinth with a pillow under the head. Stabilization was achieved as shown in Figure 3. The dominant shoulder was placed in a position of adduction of 0° and the elbow was flexed to 90° as before. Active arm adduction and maintenance of 80% of individual's MFO was done as in Test A. (Figure 4)

Test D (side-lying passive adduction): The subject lay on their side and upper extremity positioned as described in Test C. Adduction force was maintained at less than 60% MFO as described in Test B. (Figure 4)

Figure 3. *Stabilization of Shoulder in Side-Lying Testing Position. This is the traditional position for testing the infraspinatus muscle while side-lying. Stabilization is performed through the superior scapula by a corollary researcher.*

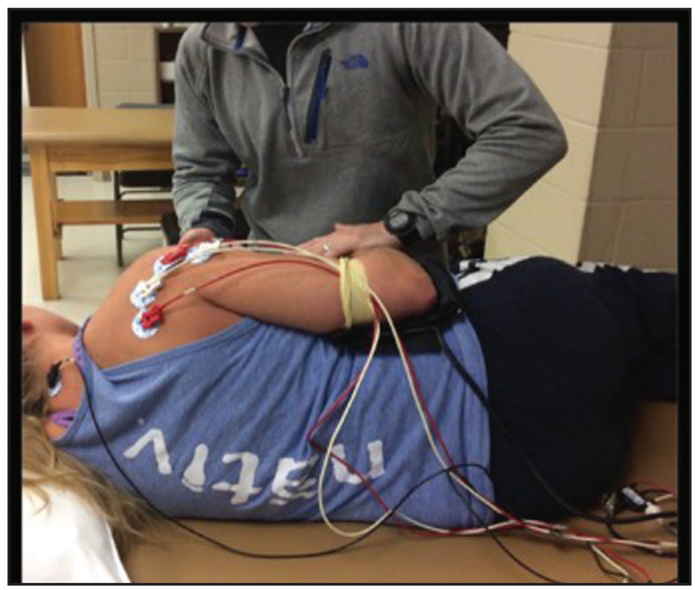

Figure 4. *Test Positions C and D: Side-Lying Active or Passive Adduction. The researcher is applying resistance to external rotation for either condition. In test position C the subject would be actively adducting into the blood pressure cuff at 80% of maximal effort and in test position D the subject would be asked to not adduct into the blood pressure cuff. The stabilization of the scapula would be performed by a second researcher not shown in this picture.*

External resistance was applied until failure (as in a "break" manual muscle test). For each test, a five-second isometric external rotation contraction was produced a total of three times with one minute of rest provided between each repetition. In order to avoid the artifact during initial activation and the "break", the middle portion of the EMG was used for analysis. The mean RMS of the three trials (over a three second window) was averaged for each muscle and then compared across test conditions.

Standardized instructions were given to each subject prior to testing. Results of the pressure generated by the subject on the cuff, as monitored by the AS gauge, were submitted to the researcher responsible for data entry. The subjects were blinded from the EMG data collected during the study.

DATA ANALYSIS

The SPSS Statistical Package for Windows (version 22; IBM SPSS, Armonk, NY) to analyze differences in the mean RMS of the IM and PD across the four test conditions. The comparison of mean values from EMG for all the test conditions were calculated. Two ANOVAs with repeated measures and a Bonferroni correction for distribution were used with the alpha level set at $p < 0.05$.

RESULTS

The mean EMG values in microvolts (μV) for each for each of the test positions for the PD are presented in Table 1. The mean EMG values for each of the test positions for the IM are presented in Table 2. The statistical comparison of mean EMG values for all test conditions were made using repeated measures ANOVAs. The repeated measures ANOVA for the PD had an F of 7.34 and demonstrated a significant difference ($p < 0.05$) for the PA between the active and passive conditions. The repeated measures ANOVA for the IM had an F value of 0.35 and there were no significant differences were found between measures ($p > 0.05$). The results of this analysis are found in Table 3. Because of these findings, a post hoc analysis was performed on the PD data and reported in Table 4. The PD mean EMG activity was

Table 1. *Means of EMG Activity of the Posterior Deltoid.*

Deltoid Group	Mean (μV)	Std. Deviation (μV)	n	95% CI Lower Bound	95% CI Upper Bound
A	194.57	126.66	34	147.27	241.86
B	301.07	232.42	34	214.28	387.86
C	217.90	139.20	34	165.92	269.88
D	315.60	202.61	34	239.94	391.26

n = number of subjects, CI = Confidence Interval, μV = microvolts
Group A = Seated Active Adduction
Group B = Seated Passive Adduction
Group C = Side-lying Active Adduction
Group D = Side-Lying Passive Adduction

Table 2. *Means of EMG Activity of the Infraspinatus.*

Infraspinatus Group	Mean (μV)	Std. Deviation (μV)	n	95% CI Lower Bound	95% CI Upper Bound
A	288.07	182.80	34	219.81	356.33
B	277.23	184.82	34	208.22	346.25
C	295.23	196.75	34	221.77	368.70
D	276.73	205.18	34	200.12	353.35

n = number of subjects, CI = Confidence Interval, μV = microvolts
Group A = Seated Active Adduction
Group B = Seated Passive Adduction
Group C = Side-lying Active Adduction
Group D = Side-Lying Passive Adduction

Table 3. *Repeated Measures ANOVA.*

Variables	Wilks' Lambda	F	Hypothesis df	Error df	p-value
Posterior Deltoid	.55	7.34	3.00	27.00	.001*
Infraspinatus	.96	.35	3.00	27.00	.792

*. The mean difference is significant at the p < .05 level.
df = degrees of freedo

Table 4. *Post Hoc Comparison of Posterior Deltoid Means.*

Groups		Mean Difference (μV)	Std. Error	p-value
A	B	-106.50*	31.51	.002*
	C	-23.33	15.76	.150
	D	-121.03*	28.16	.000*
B	A	106.50*	31.51	.002*
	C	83.17*	27.72	.005*
	D	-14.53	27.38	.600
C	A	23.33	15.76	.150
	B	-83.17*	27.72	.005*
	D	-97.70*	21.29	.000*
D	A	121.03*	28.16	.000*
	B	14.53	27.38	.600
	C	97.70*	21.29	.000*

*=. The mean difference is significant at the p < .05 level.
μV = microvolts
Group A = Seated Active Adduction
Group B = Seated Passive Adduction
Group C = Side-lying Active Adduction
Group D = Side-Lying Passive Adduction

significantly different between the active adduction groups and the passive adduction groups in both sitting and in side-lying positions ($p < 0.05$). The difference between means from seated passive adduction and side-lying passive adduction of the PD were not significantly different ($p > 0.05$). The mean EMG activity of the PD during both positions and all four testing procedures through post hoc testing is found in Table 4. A post hoc analysis did not reveal any significant difference in the mean EMG activity of the IM between either of the test positions or adduction conditions.

DISCUSSION

The intention of this study was to find a clinically applicable method to test the infraspinatus muscle which might reduce the EMG activity and contribution of the deltoid musculature. Jensen et al[22] stated the PD is active during external rotation testing in most subjects. Reinold et al[10] reported that the best position to reduce deltoid activity while increasing activity of the IM (and teres minor) musculature is in 0° of abduction in a side-lying position. Other authors have suggested other exercises and testing procedures for the IM but none have been found to be a more accurate test for the IM more than the infraspinatus test.[23] The current study found the PD contributed greatly during these same tests intended to test the infraspinatus, even in the 0° abducted position. This deltoid activity could easily contribute to the resistance given by a subject and confuse test outcomes, especially when testing an injured shoulder. Ha et al[24] found significant activity of the deltoid in both the side-lying and in the upright positions with resisted external rotation even though the side-lying position elicited the least PD activity compared to four different positions studied. Park et al[25] suggested shoulders may work differently when the rotator cuff is injured and found increases in PD EMG activity in persons with a rotator cuff injury. Clisby et al[26] suggest that the rotator cuff and deltoid are imbalanced in patients with rotator cuff injury and the goal of rehabilitation is to reduce the activity of the deltoid and increase the activation of the rotator cuff. These authors also found that, whether the shoulder was elevated or adducted passively, continual activity of the deltoid occurred, especially in those persons with shoulder pathology.[26] In the present study, the PD was significantly active during traditional IM testing in both the seated and side-lying positions with 0° of abduction in agreement with the authors cited, and could create inaccurate testing results when performing manual muscle testing because of contributions and activity of the PD to assist in countering the resistance.

The results of this study demonstrated less PD EMG activity when performing forceful active adduction during resisted external rotation. When subjects actively adducted during IM testing during both seated and side-lying external rotation with the arm in 0° of abduction, the PD was significantly less active than when the active adduction was not performed during this testing. This suggests that the PD contributed less to the external rotation output during manual muscle testing. However, the IM activity was not significantly different whether the subject was adducting or not adducting. This would suggest the IM remained active and was contracting at a similar level while the PD was contributing less to the action. If the IM had decreased in EMG activity with active adduction, then the action of adduction could be interpreted as reducing the contraction of shoulder musculature that are abductors. Thus, the IM may be more accurately tested in this test position, as the PD was no longer assisting as much in attempting to externally rotate.

A towel roll was not used at the side but the use of an AS for adduction force was utilized during this session. Other authors have suggested a towel roll or other object to be placed between the elbow and the side in the infraspinatus test position to decrease the activity of the deltoid during the testing procedures.[8,22,27] However, the use of the towel roll was not shown to be as effective at reducing activity of the deltoid after the Reinold et al[10] study was completed, as these authors found increased activity in supporting muscles during testing, including the teres minor, and continued significant deltoid activity in normal shoulders.

Reciprocal inhibition was used to reduce the contribution of the deltoid during two commonly used testing procedures for the external rotators. This procedure required active adduction be performed while testing the external rotators. The mechanical properties of the posterior deltoid compared with the infraspinatus support the deltoid having a primary torque-producing role rather than the stabilization role of the IM.[22] The deltoid muscle's ability and tendency to substitute for the rotator cuff, especially when an injury has occurred, make the evaluation of the amount of strength loss and percentage of damage to the IM difficult.[26] Reciprocal inhibition has been suggested as a method to reduce the activity of a muscle group.[28-31] Active adduction during infraspinatus testing in this study allowed no significant change in EMG activity of the IM while significantly reducing the EMG activity of the PD. Active adduction while performing IM testing has not been explored as a method to reduce deltoid activity in any previous study.

Limitations

This study has several limitations. First, this study only utilized data from 34 healthy subjects and may differ in those with shoulder pain or pathology. Though the post hoc power analysis was favorable for this number, more numbers would be necessary to establish reliability data for these new test positions. Second, all positions that have been suggested for IM clinical testing or treatment were not tested.[3,32,33] Other positions have been offered through previous studies, but these other positions have been shown to have increased posterior or middle deltoid activity along with increased IM activity.[10,11,26,34,35] This study did not attempt to try reciprocal inhibition techniques to quiet PD activity in any of these other positions. Third, the manual resistance applied toward external rotation was not quantified using any form of dynamometer. The subjects in this study varied greatly in strength and size and differing resistance was used to reach a point of failure for each individual. Use of a manual dynamometer during the collection of data might help describe differences in levels of resistance and recruitment of deltoid musculature as suggested by another author.[32] Finally, other levels of adduction resistance against the cuff could have been used. In this study, 80% of maximal contraction was utilized. Other levels of adduction might have differing results in the inhibition of the PD musculature. Attempts to find ways to inhibit the PD were not effective using light to moderate adduction pressures (increase of 20-40 mmHg) by this same research lab in previous studies. Eighty percent of maximal contraction was chosen as a means to test effects of resistance in the upper range of adduction activity for subjects.

CONCLUSIONS

In this study, aggressive AA during the testing of the IM (seated and side-lying) resulted in significantly less activity in the PD while not reducing the EMG activity of the IM. The results of this study suggest that clinicians may be able to reduce the activity of the PD by having the subject actively adduct the humerus before applying manual resistance during IM testing. When testing for injury to the IM, either a side-lying or seated position, using 80% or greater adduction pressure, should reduce the contribution of the PD.

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